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COMMUNICATION SYSTEM AND METHOD

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT DONALD. H. STEINBRECHER, employee of the United States Government, citizen of the United States of America and resident of Brookline, County of Norfolk, Commonwealth of Massachusetts, has invented certain new and useful improvements entitled as set forth above of which the following is a specification:

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3 COMMUNICATION SYSTEM AND METHOD

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5 STATEMENT OF GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used
7 by or for the Government of the United States of America for
8 governmental purposes without the payment of any royalties
9 thereon or therefor.

10
11 CROSS REFERENCE TO OTHER RELATED APPLICATIONS

12 Not applicable.

13
14 BACKGROUND OF THE INVENTION

15
16 (1) Field Of The Invention

17 The present invention generally relates to a wireless
18 communication system.

19 (2) Description of the Related Art

20 Future approaches to spectrum allocation will likely avoid
21 dedicated spectrum assignments in favor of schemes that allow
22 users to occupy certain frequency bands only when a
23 communications link is established. Spectrum allocation will also
24 favor spectrum-use schemes that use a bandwidth-on-demand
25 architecture so that the bandwidth in use at any specific time is

1 not larger than necessary to support the data transfer
2 requirement at that time. It is also anticipated that spectrum
3 use schemes capable of searching for temporally free spectrum
4 will be favored over static frequency assignment.

5 What is needed is a wireless communication scheme that is
6 configured to dynamically utilize available spectrum in an
7 efficient manner in accordance with the future trends and
8 approaches to spectrum allocation discussed in the foregoing
9 description.

10

11 SUMMARY OF THE INVENTION

12 The present invention is directed to a wireless
13 communication system that utilizes the minimum bandwidth
14 necessary to achieve accurate and effective communication. The
15 communication system of the present invention provides a
16 versatile addressing scheme that allows multiple users to
17 communicate over narrow-band channels of a relatively wide-band
18 communication link. The communication system of the present
19 invention is configured to dynamically vary the signal bandwidth
20 between a transmitter and a receiver in an environment where
21 available bandwidth may only exist in non-contiguous small-
22 bandwidth channels or increments. The communication system of
23 the present invention is also configured to (i) combine a set of
24 the small-bandwidth non-contiguous channels to form the required
25 instantaneous signal bandwidth, (ii) use different channels

1 outside the original set of channels as other channels become
2 available, (iii) use different channels outside the original set
3 of channels as channels within the original set become
4 unavailable and (iv) vary the number of channels utilized to
5 accommodate a time-varying signal-bandwidth requirements needed
6 to effect communication.

7 The communication system of the present invention utilizes a
8 pair of complementary signal processing schemes for modulation
9 and transmission of information, and for reception and
10 demodulation of the transmitted information. In accordance with
11 the present invention, the communication system utilizes a
12 portion of a wide-band communication link. The first signal
13 processing scheme is implemented in a transmitting system that
14 receives an input sample stream that comprises at least one group
15 of a plurality of sample positions. Each sample position
16 contains a multi-bit Nyquist-rate sample that defines a
17 particular narrow-band digital image. The number of bits in each
18 sample is adjusted by the communication system to provide the
19 accuracy required to achieve accurate and effective
20 communication. Thus, a particular narrow-band digital image is
21 formed by the samples occupying the same sample position within
22 each group of the plurality of sample positions. Each narrow-band
23 digital image is converted to a wide-band digital image and then
24 translated to a narrow-band analog signal. The narrow-band
25 analog signal has a bandwidth that is the same as the bandwidth

1 of any of the narrow-band channels that form the wide-bandwidth
2 portion of the RF spectrum. The narrow-band analog signal is
3 inputted into a RF (radio frequency) transmitter module that up-
4 converts the narrow-band analog signal to a selected frequency
5 band where the signal is amplified and coupled to a transmitting
6 antenna. The antenna broadcasts the signal over a narrow-band
7 channel of the wide-band communications link. The aforementioned
8 narrow-band channel corresponds to the sample position used to
9 generate the wide-band digital image.

10 The communications system further comprises circuitry for
11 reception and demodulation of the transmitted signal. The
12 receiving system, which cooperates with a receiving antenna,
13 detects the narrow-band analog signal transmitted over the
14 narrow-band channel. The receiving system includes processing
15 circuitry that translates the received analog signal to a
16 frequency that is suitable for an analog-to-digital conversion
17 process. The analog-to-digital conversion process generates a
18 wide-band composite digital image. The wide-band digital image
19 is then further processed so as to decompose the wide-band
20 digital image into a plurality of narrow-band digital image
21 waveforms. Each narrow-band digital waveform is represented by a
22 plurality of multi-bit Nyquist-rate samples that are assigned to
23 a sample position that is the same as the sample position used to
24 generate the transmitted narrow-band analog signal. Thus, if the
25 original narrow-band digital waveform in the transmitting system

1 is defined by samples associated with a Kth sample position, then
2 the transmission of the narrow-band analog signal takes place
3 over the Kth narrow-band channel of the communications link, and
4 the received signal is decomposed into a plurality of narrow-band
5 digital images that are matched to the Kth sample position of an
6 output sample stream. Thus, samples associated with the Kth
7 sample position prior to transmission remain associated with the
8 Kth sample position when the received signal is processed and
9 decomposed.

10 Thus, in one aspect, the present invention is directed to an
11 apparatus for effecting wireless communication, comprising an RF
12 bandwidth partitioner to partition a wide bandwidth portion of
13 the RF spectrum into a plurality of narrow-band channels wherein
14 all of the narrow-band channels have a narrow-band channel
15 bandwidth, a data sample source which provides at least one group
16 of time-domain data samples that are associated with a particular
17 sample position and which define a narrow-band digital image
18 wherein the sample position defines a particular one of the
19 narrow-band channels, a first processor resource to derive a
20 wide-band digital image in the frequency domain from the narrow-
21 band digital image, a digital-to-analog converter to convert the
22 wide-band digital image into a narrow-band analog signal, and a
23 transmitter module to transmit a narrow-band analog signal over a
24 particular one of the narrow-band channels that corresponds to
25 the particular sample position. The transmitter module comprises

1 an up-converter to transform the narrow-band analog signal to a
2 predetermined RF frequency. The apparatus further includes a
3 monitoring instrumentally to determine which of the narrow-band
4 channels are available for use, and an input for receiving the
5 transmitted narrow-band signal. The apparatus also includes a
6 second processor resource to derive a wide-band digital image
7 signal in the frequency domain from the received signal, a third
8 processor resource to derive a plurality of narrow-band digital
9 images from the wide band digital image wherein each of the
10 plurality of narrow-band digital images are represented by time-
11 domain data samples, and a data storage device to store the time-
12 domain data samples that define the plurality of narrow-band
13 digital images in the sample position that corresponds to the
14 narrow-band channel occupied by the transmitted narrow-band
15 analog signal.

16

17 BRIEF DESCRIPTION OF THE DRAWINGS

18 The figures are for illustration purposes only and are not
19 drawn to scale. The invention itself, however, both as to
20 organization and method of operation, may best be understood by
21 reference to the detailed description which follows taken in
22 conjunction with the accompanying drawings in which:

23 FIG. 1 is a diagram that illustrates a radio-frequency
24 bandwidth partitioned into a plurality of N equal narrow-band
25 segments.

1 FIG. 2 is a block diagram of the communications system of the
2 present invention.

3 DESCRIPTION OF THE PREFERRED EMBODIMENT

4 In describing the preferred embodiments of the present
5 invention, reference will be made herein to FIGS. 1 and 2 of the
6 drawings in which like numerals refer to like features of the
7 invention.

8 As used herein, the terms "narrow-band" and "narrow-
9 bandwidth" are used interchangeably and have the same meaning.

10 Referring to FIG. 1, the communication system of the present
11 invention utilizes a wide-bandwidth portion 10 of the RF (radio
12 frequency) spectrum. The wide-bandwidth portion 10 has a
13 bandwidth BW. In accordance with the present invention, an RF
14 bandwidth partitioner device or other suitable RF bandwidth
15 processing device is used to partition bandwidth BW into N equal
16 contiguous narrow-band channels or segments 12. Each channel 12
17 has a bandwidth BN such that $N \times BN = BW$. For example, a wide-
18 bandwidth BW of 15.36 MHz may be partitioned into narrow 30.0 kHz
19 bands. In such an example, $N = 512$ (i.e. 512 narrow-bandwidth
20 channels). In one embodiment, a software algorithm implemented
21 by a microprocessor or computer is used to generate information
22 defining the bandwidth of each channel 12. In such an
23 embodiment, information defining the desired number of narrow-
24 band channels and the total available bandwidth BW is inputted
25 into the aforementioned microprocessor or computer.

1 Bandwidth BN is at least the minimum required bandwidth to
2 effect efficient and accurate transmission of data. The lower
3 frequency edge of bandwidth BW is designated as BWL and the
4 higher frequency edge of bandwidth BW is designated by BWH such
5 that $BWH = BWL + BW$. The narrow-band channels 12 are indexed
6 from BN(1) to BN(N), starting at the lowest frequency narrow-band
7 channel 12a, thereby forming the sequence BN(1), BN(2) . . .
8 BN(N). An arbitrary narrow-band channel is indicated by numeral
9 12b and designated by BN(k) wherein $0 < K < (N+1)$. The lower
10 frequency edge of BN(k) equals $BWL + (K-1)BN$ and the higher
11 frequency edge of BN(k) equals $BWH - (N-k)BN$.

12 The Nyquist sample rate for BW is $2BW$ and the Nyquist sample
13 rate for BN is $2BN$. An analog signal occupying a narrow
14 bandwidth BN may be described by a digital image signal of $2BN$
15 samples/second. Similarly, the composite analog signal occupying
16 the wide bandwidth BW may be described by a digital image signal
17 of $2BW$ samples/second.

18 Referring to FIG. 2, there is shown a communication system
19 14 of the present invention. A communication system 14 generally
20 comprises transmitting system 16 and receiving system 18.

21 Transmitting system 16 generally comprises antenna 20,
22 signal processor 26, digital-to-analog converter 28, and RF
23 transmitter module 30. An input data sample stream 32 defines
24 the digital data or information that is to be transmitted.
25 Sample stream 32 comprises a plurality of groups 34 of N

1 contiguous individual samples 36. Each sample 36 has a
2 corresponding sample position. For example, sample 36a in each
3 group 34 has a sample position "K". The actual quantity N of
4 samples 36 in each stream 34 is equal to the number N of narrow-
5 band channels such that there is a one-to-one relationship
6 between each sample position and a corresponding narrow-band
7 channel. Thus, the sample having sample position K corresponds
8 to the narrow-band channel $BN(K)$.

9 Each sample 36 is a multi-bit word. The number of bits in
10 the multi-bit word depends upon the required or desired accuracy.
11 Each sample 36 represents a narrow-band digital image having a
12 bandwidth BN . Each sample 36 has a Nyquist sampling rate of $2BN$.
13 In one embodiment, each sample 36 contains a preamble that
14 defines the sample position of that particular sample and the
15 narrow-band channel that is to be used when transmitting signals
16 based on samples extracted from that particular sample position
17 in each group 34.

18 Signal processor 26 is preferably a digital signal processor
19 ("DSP") such as a digital spectrum encoder. Signal processor 26
20 includes other processing circuitry such as multi-rate filters
21 and/or commutator circuitry. Processor 26 further comprises
22 electronic circuitry that can effect handling of data in parallel
23 or serial form. Processor 26 also comprises data storage devices
24 such as a random-access-memory (RAM). Input data sample stream
25 32 is inputted into signal processor 26. Processor 26

1 synthesizes a wide-bandwidth digital image signal 38 having
2 bandwidth BW. Each digital image signal 38 is formed from the
3 time-domain samples extracted from a particular sample position.
4 For example, processor 26 uses the narrow-band digital images
5 formed by the samples extracted from the Kth sample position of
6 each group 34 to form a wide-bandwidth digital image signal 38
7 having a sample rate of $2BW$ samples/second. Signal 38 is a
8 frequency domain signal having a plurality of frequency domain
9 samples wherein each frequency domain sample corresponds to a
10 particular time domain sample. Thus, if there are 512 time-
11 domain samples, there will be 512 frequency domain samples.
12 Therefore, the Kth sample position of the time domain data sample
13 stream, which was inputted into signal processor 26, corresponds
14 to the Kth sample position in the frequency domain sample stream
15 of signal 38.

16 The rate at which samples 36 are inputted into signal
17 processor 26 can be varied from $2BN$ samples/second to $2BW$
18 samples/second.

19 However, in a preferred embodiment, signal processor 26
20 always outputs signal 38 having a sample rate of $2BW$
21 samples/second.

22 Wide-band digital image signal 38 is inputted into digital-
23 to-analog (DAC) converter 28. DAC 28 converts digital image
24 signal 38 into a narrow-band analog signal 40 and then translates
25 the narrow-band analog signal 40 to a bandwidth that matches one

1 of the narrow-band channels 12. Such translation process
2 utilizes the preamble information, described in the foregoing
3 description, to determine the narrow-bandwidth to which the
4 narrow-band analog signal is translated.

5 The translated narrow-band analog signal 40 is inputted into
6 an RF (radio frequency) transmitter module 30 that up-converts
7 the narrow-band analog signal to a selected frequency band. The
8 up-converted signal is then amplified and outputted to antenna
9 20. Antenna 20 broadcasts narrow-band signal 42 over the
10 designated narrow-band channel of wide-bandwidth portion 10
11 shown in FIG. 1.

12 Thus, the narrow-band analog signal occupying the narrow-
13 bandwidth channel $BN(K)$, indicated by numeral 12a, is formed by
14 the samples occupying the K th sample position in each successive
15 group 34 of N samples 36. This relationship is true for all
16 sample positions K in the set $0 < K < (N+1)$.

17 Referring to FIG. 2, signal 42 is received and processed by
18 receiving system 18. Receiving system 18 implements a signal
19 processing method that is the reverse of the signal processing
20 method implemented by transmitting system 16. Receiving system
21 18 includes antenna 44 which receives transmitted signal 42.
22 Antenna 44 outputs received signal 42 for input into receiver
23 module 50. Receiver module 50 amplifies the received signal and,
24 if necessary, applies particular filtering functions to the
25 received signal. Receiver module 50 also down-converts the

1 received signal to a frequency suitable for an analog-to-digital
2 conversion process. The output of receiver module 50 is inputted
3 into analog-to-digital converter 52 which outputs a composite
4 wide-band digital image 54 having a sample rate of $2BW$. Wide-
5 band digital image 54 is then inputted into signal processor 56.
6 In one embodiment, signal processor module 56 is configured as a
7 digital signal processor such as a digital spectrum decoder.
8 Processor module 56 decodes wide-band digital image 54 into a
9 plurality of narrow-band digital images 58. Each narrow-band
10 digital image 58 is represented by a multi-bit sample having a
11 sample rate of $2BN$. The multi-bit samples form an output sample
12 stream 58 that comprises a plurality of groups 60 of N contiguous
13 multi-bit samples 62. Each sample 62 has a corresponding sample
14 position. For example, the sample at the K th position is
15 indicated by numeral 62a. If the narrow-band analog signal was
16 broadcast over the K th narrow-band channel $BN(K)$, indicated by
17 numeral 12a, then the resulting narrow-band digital images 58 are
18 decomposed into multi-bit samples in the K th sample position in
19 each group 60 of samples 62. Thus, the samples occupying the K^{th}
20 sample position in each successive group 60 of samples 62
21 comprises the digital image of the signal occupying the K th
22 narrow bandwidth channel $BN(k)$, indicated by numeral 12a, in
23 FIG. 1. This relationship is true for all sample positions K in
24 the set $0 < K < (N+1)$.

25 Signal processor 56 comprises electronic data handling

1 circuitry, known in the art, for processing data samples in
2 serial and/or parallel format, and data storage devices such as a
3 random-access-memory (RAM).

4 Thus, the narrow-band digital image comprising the samples
5 occupying the K th sample position in each successive group 60 of
6 N samples 62 is substantially identical to the narrow-band
7 digital image comprising the samples occupying the K th sample
8 position in each successive group 34 of N samples 36.

9 Thus, the communications system and method of the present
10 invention uses only certain narrow-bandwidth channels of a wide-
11 bandwidth portion of the RF spectrum.

12 The bandwidth between transmitting and receiving systems may
13 be changed in increments of BN by adding digital images with
14 different values of K . If the values of K chosen for different
15 digital images are not consecutive, then the bands of
16 transmission, $BN(K)$, are not contiguous. Thus, the bandwidth
17 between transmitter and receiver can be increased or decreased in
18 increments of BN as necessary for the transfer of information by
19 using un-occupied narrow bands $BN(k)$.

20 An important feature of the communications system of the
21 present invention is that more than one narrow-band channel 12
22 can be used to effect communication. Another important feature
23 is that the narrow-band channels utilized need not be contiguous.
24 The communications system of the present invention can also be
25 used to provide system redundancy if necessary. In such a

1 configuration, the same information is transmitted over a
2 plurality of narrow-band channels 12.

3 The communications system and method of the present
4 invention can be used with a monitoring or scanning system that
5 monitors the narrow-band channels to determine which of the
6 channels are available and which of the narrow-band channels are
7 in use.

8 The communications system and method of the present
9 invention can be used to form the basis for other types of
10 communication schemes, e.g. frequency hopping systems, spread
11 spectrum systems, frequency division multiple-access systems,
12 etc. Furthermore, transmitting system 16 and receiving system 18
13 can be combined to form a transceiver. In such a configuration,
14 a single antenna can be used to transmit and receive signals.

15 While the present invention has been particularly described,
16 in conjunction with a specific preferred embodiment, it is
17 evident that many alternatives, modifications and variations will
18 be apparent to those skilled in the art in light of the foregoing
19 description. It is therefore contemplated that the appended
20 claims will embrace any such alternatives, modifications and
21 variations as falling within the true scope and spirit of the
22 present invention.

3 COMMUNICATION SYSTEM AND METHOD

5 ABSTRACT OF THE DISCLOSURE

6 A wireless communication system and method. A wide-band
7 analog signal is digitally sampled to form a digital replica.
8 The digital replica is transmitted over a wireless channel using
9 a subset of available narrow-band channels that may or may not be
10 contiguous. Signal parameters may be dynamically adjusted in
11 order to utilize particular portions of the spectrum when those
12 portions of the spectrum are not being used. Channels are
13 selected on a sample by sample basis and multiple channels may be
14 selected simultaneously in order to dynamically increase
15 bandwidth when vacant channels are available. Thus, the data
16 rate is increased on a bandwidth-available basis.

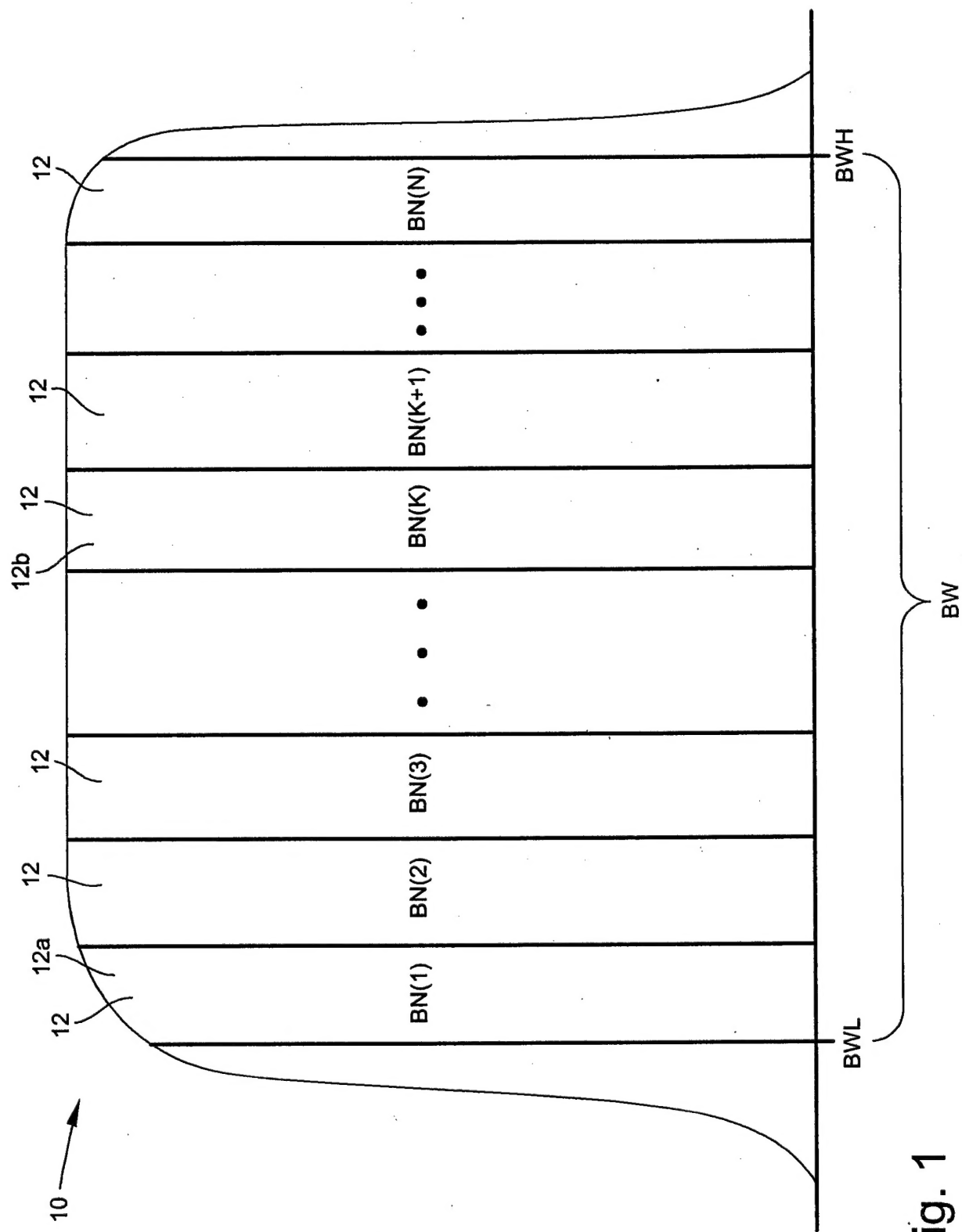


Fig. 1

Fig.2

